

High doped p-type GaN growth by newly developed alternative co-doping technique

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Realization of high doped p-type GaN and AlGaIn is essentially important for optical and electrical devices using nitride compounds. So far, co-doping is one of possible candidates theoretically predicted to get high doped p-type GaN and AlGaIn. However, no one has been successful to get the high doped p-type GaN by conventional co-doping technique. We have succeeded in realizing high doped p-type GaN with carrier density of more than $10^{19}/\text{cm}^3$ using newly developed alternative co-doping technique. In our technique GaN is grown using alternative supply of TMG and NH_3 with a sequence of 1sec with 3sec interval for each source gas under low pressure MOVPE. To keep the stoichiometry a small amount of NH_3 is continuously fed into a reactor. Si source gas is fed at a moment of TMG feeding time and Mg source gas is fed at the moment just after the feeding of Si source, within the purging time of TMG.

On the TMG feeding period, Si and Mg can easily migrate on the Ga surface and can make complex to act as a shallow acceptor predicted by theory. This migration of Si and Mg on a Ga surface is essential to realize co-doping effect. When the Si and Mg are doped simultaneously with TMG and NH_3 , Si and Mg can not migrate so easily and are difficult to make the complex.

This is the reason why the co-doping done by conventional technique was not successful. We observed the hole carrier density by Hall effect measurement at RT depending on Si source dose rate with a constant feeding rate of Mg source gas. We also observed photoluminescence related to band to acceptor emission. As results, we have found the density of hole carrier depends on the dose rate of Si source gas. The hole density can be more than $10^{19}/\text{cm}^3$ with a mobility of $0.5 \text{ cm}^2/\text{v. sec}$. Without Si co-doping the hole carrier density was $2 \times 10^{18}/\text{cm}^3$. We observed 4 or 5 times enhancement of carriers density. In the co-doped sample, band to acceptor luminescence shifts to higher energy side. This suggests that the acceptor level decreases by this co-doping. In conclusion we can emphasize that the hole carrier density is increased 4 to 5 times by newly developed alternative co-doping technique in comparison with the case without co-doping and the carrier density is realized to be more than $10^{19}/\text{cm}^3$.